Thesis.

Cariss.

DESIGN

OF AN

INDICATOR SPRING TESTER

Wm. H. Cariss.

In order to determine the actual pressures and their rate of change in engine cylinders the Steam Indicator has been evolved. It has been and still is of great service to engineers. The natural sources of error of anything mechanical, friction, wearing and lost motion, have been reduced to a minimum and the instrument now seems to have reached a fixed general design.

The vital part of the indicator is the spring, the compression or elongation of which, under a

pressure on the piston, gives the height of the line drawn on the card. By this height and the Spring Scale we calculate the pressure on the piston. But how do we know what this Spring Scale is? The makers mark each spring with its scale. But when in use we can hardly expect them to be accurately what they are marked. They are in a different indicator and perhaps under entirely different conditions. So the instrument should be calibrated under conditions as nearly as possible like

those under which it is
to be used.

As, in the majority of
cases it is used on a steam
engine cylinder, steam pressure
is used in the calibration.
The indicator is attached to
a cylinder or drum, steam
admitted and the pressure
varied, lines being drawn
on the indicator card at
certain known pressures. Good
methods are now in use to
determine the Spring Scale
having given the calibration
card with lines drawn at
the various pressures. To
obtain this card and know
accurately what the pressures

corresponding to each line are, is another proposition and one that has been given far too little attention.

The need of a good and uniform method of calibration has been clearly pointed out by Prof. D. S. Jacobus in the Transactions of the American Society of Mechanical Engineers. Vol XX p 404. In a comment on this article by Prof. W. F. M. Goss a tester is described involving a novel apparatus for maintaining any desired pressure.

This idea was made use of in this design. A drawing for such an apparatus

is shown on Sheet-No 2. It might be called a relief valve adjustable by weights for different pressures. The principle is simply:- Weight on a free piston in a vertical cylinder in which there is a gas × area of the piston = pressure per. sq. in. in the cylinder. At the bottom A of the cylinder it is to be attached to a steam drum. Tapered grooves are cut opposite each other on inside of the cylinder as shown C,C, These terminate at the top in a circular slot D in the cylinder wall. This slot at E opens to a hole from

the exterior. If the pressure under the piston is greater than the weight of the piston and the weights on it the latter will rise. As they do they uncover the tapered-grooves gradually and the steam in the cylinder escapes untill its pressure has fallen to that on the plunger. The decrease in pressure is due to the increase in volume, or to the decrease in weight of steam in the drum. If the weight in the drum be kept constant by an inflow at some other point then the piston will find a position where

it leaves sufficient opening by the grooves for the weight to decrease as fast as it is being increased at the other opening in the drum. While such a flow is going on the pressure in the drum to which the cylinder is attached remains constant. Such a flow will (will) result from any pressure we may wish to put downward on the piston face. For if the inflow is greater than the outflow, with the piston in a certain position, a rise in pressure in the drum will result which will raise the piston and make the outlet opening

through the grooves larger;
or if the inflow is insufficient
the piston will fall, and
so adjust itself to maintain
the proper outflow at the
pressure. As the piston is
then in equilibrium the pressure
in the drum is = wt of piston,
~~weight~~ pan & weights ÷ area piston,
per. sq. in. above the atmosphere.
The area of the piston is $\frac{1}{4}$ sq. in.
The weight pan and piston weigh
$1\frac{1}{4}$ lbs. so the minimum attainable
pressure is 5 lbs. Weights 6" diam.
as used with the Crosby Standard
Gauge Tester are to be used.

For testing below
the atmospheric pressure
the mercury column has

been almost universally used for determining the pressure. Variation of pressure in the drum were produced by different rates of inflow and exhaust from the drum. The calibration lines were drawn as the top of the mercury column passed certain points. From these points or heights the pressure was calculated. This method has many disadvantages and errors. Water collects on the top of the column There is considerable friction between the mercury and the tube. The moving column has inertia. So the height of the column cannot give us

accurately the pressure in the steam drum at the instant the line was drawn on the calibration card.

An endeavor to find a substitute has resulted thus. It seems rational to think that if the other apparatus works for pressures above the atmosphere in the position shown it would do the same for pressures below the atmosphere if turned upside down. In this position the weight of the plunger and weights subtracted from the pressure of the air (as they are in opposite directions) is equal to the pres-

sure required on the other end of the plunger to hold it in equlibrium.

Sheets No. 3 & 4 are drawings for this apparatus. Sheet No. 3 shows the piston and cylinder. The ~~area~~es of the piston is made ½ sq. in. It will be more accurate than a smaller one because the friction against the cylinder walls will ~~be~~ less in proportion to the weight. The grooves are made deeper in this case than in the other for two reasons:- the plunger is larger, and the steam dealt with is a great deal lighter and must pass

through the drum quickly.

Sheet No 4 shows the weight-hanger, weight-base and weights. The diameter of the weights was determined on and their thickness worked out for each to weigh 1 lb. and thus in the instrument be equivilent to 2 lbs. per sq. in.

Diameter of weights = 3"

$3^2 \times \frac{\pi}{4} = 7.07$ sq. in.

$7.07 \times t \times .26 = 1$ lb

$t = \frac{1}{7.07 \times .26} = .545$ Thickness $= \frac{9}{16}$"

The calculations of the weight of piston, weight-frame and weight-base follows. It was adjusted to = 1.5 lbs as this was found to be the minimum attainable to give a whole

number of lbs. per. sq. in. as the instrument is used.

Plunger.

$\frac{\pi}{4} \times \left(\frac{1}{2}\right)^2 \times \frac{3}{8} = \frac{\pi}{16} \times \frac{3}{8} = .0737$ cu. in.

$\frac{\pi}{4} \times \frac{3}{4} \times 3'' = .785 \times \frac{27}{16} = 1.32$ " "

$\frac{1}{2} \times 3.25 = \text{-----}\ 1.63$

3.02 cu. in. of steel

$3.02 \times .28 = .846$ lbs.

Weight-Hanger.

$2 \times 3'' \times \frac{1}{4}'' = 1.5 \square''$

$2 \times 4.25'' \times \frac{3}{16}'' = 1.6 \square''$

$3.1 \square''$

$3.1 \square'' \times \frac{3}{8} = 1.16$ cu. in.

$\left[\left(\frac{7}{8}\right)^2 - \left(\frac{1}{2}\right)^2\right] \frac{\pi}{4} \times \frac{11}{16}'' = \frac{49-16}{64} \times \frac{\pi}{4} \times \frac{11}{16} = .279$ cu. in.

1.16

1.44 cu. in.

$1.44 \times .26 = .374$ lb.

Weight-base.

$7.07 \times \frac{1}{8} = .88$ cu. in.

$\left(\frac{3}{4}\right)^2 \times \frac{\pi}{4} \times \frac{1}{16} = .0276$ " "

$\left(\frac{1}{2}\right)^2 \times \frac{\pi}{4} \times \frac{5}{16} = .0614$ " "

$.97$

$.97 \times .26 = .253$ lbs.

Piston .846
Hanger .374
Base .253
1.473 lbs.

These pieces when assembled must weigh exactly 1.5 lbs. Any adjustment may easily be made on the weight base. This weight will give 3 lbs. per. sq. in. below the atmosphere in the instrument. This is the closest we can get to the atmosphere. Lower pressures are obtained by adding weights. The apparatus is shown assembled in position on Sheet No. 1.

Both these Relief valves when in working position must be plumb on their

center-lines. Any deviation will cause friction and thus error.

The complete tester is drawn assembled on Sheet No. 1. The steam drum A is supported from a table by two iron straps T, T, which are fastened to the bottom of the table as shown. At the left end the drum is connected to the steam supply pipe through a valve B. From the other end piping leads to the high pressure Relief Valve C through the valve E and the low pressure relief valve D through the valve F.

From the high pressure relief valve the exhaust is led down through the valve G and may be run into the atmosphere exhaust. From the low pressure relief valve the exhaust goes down through valve H and must be connected to a condenser of large volume which is connected to an air pump. A small pipe leading from the lower right of the drum is for drainage and is connected through valves K & L to the atmosphere exhaust and condenser respectively. From the middle of the top of the drum there

starts a $\frac{1}{4}$" pipe M which after making a loop downward comes above the table at N where a standard gauge may be attached. Short pieces of $\frac{1}{2}$" pipe with a sleeve on their upper ends will have to be screwed into the holes a, a, in the top of the drum. To these the indictors are to be attached. The middle section of the table top is to be made removeable so the valves will be of easy access for packing. Holes will be drilled in this cover for the valve stems and leads for the indicators. A groove

will have to be cut in the under side of this cover for the gage pipe M, also perhaps for the tops of valves E and F.

To make a test —

Attach the indicator to either of the openings Q, Q. Plug the other one. Now assume all valves closed to start as perhaps it is best to keep them. First for pressures above the atmosphere. Open the valve K to the exhaust and slowly open B the supply. Allow steam to blow through a minute. Place all the weights on the weight pan of C and

slowly open E full. Open G. Close K. The drum now has the maximum line pressure. The gauge N will tell what this is. Fix the weights on C to the next lowest 5 lbs. The piston in C will rise and steam will flow through. Adjust valves B and G till the piston and weights float steady. Turn the indicator cock back and forth a few times. Give the weights and thus piston of C a rotatory motion. Turn the indicator cock and draw a line on the card. Then turn the indicator cock to admit atmosphere pressure under the spring

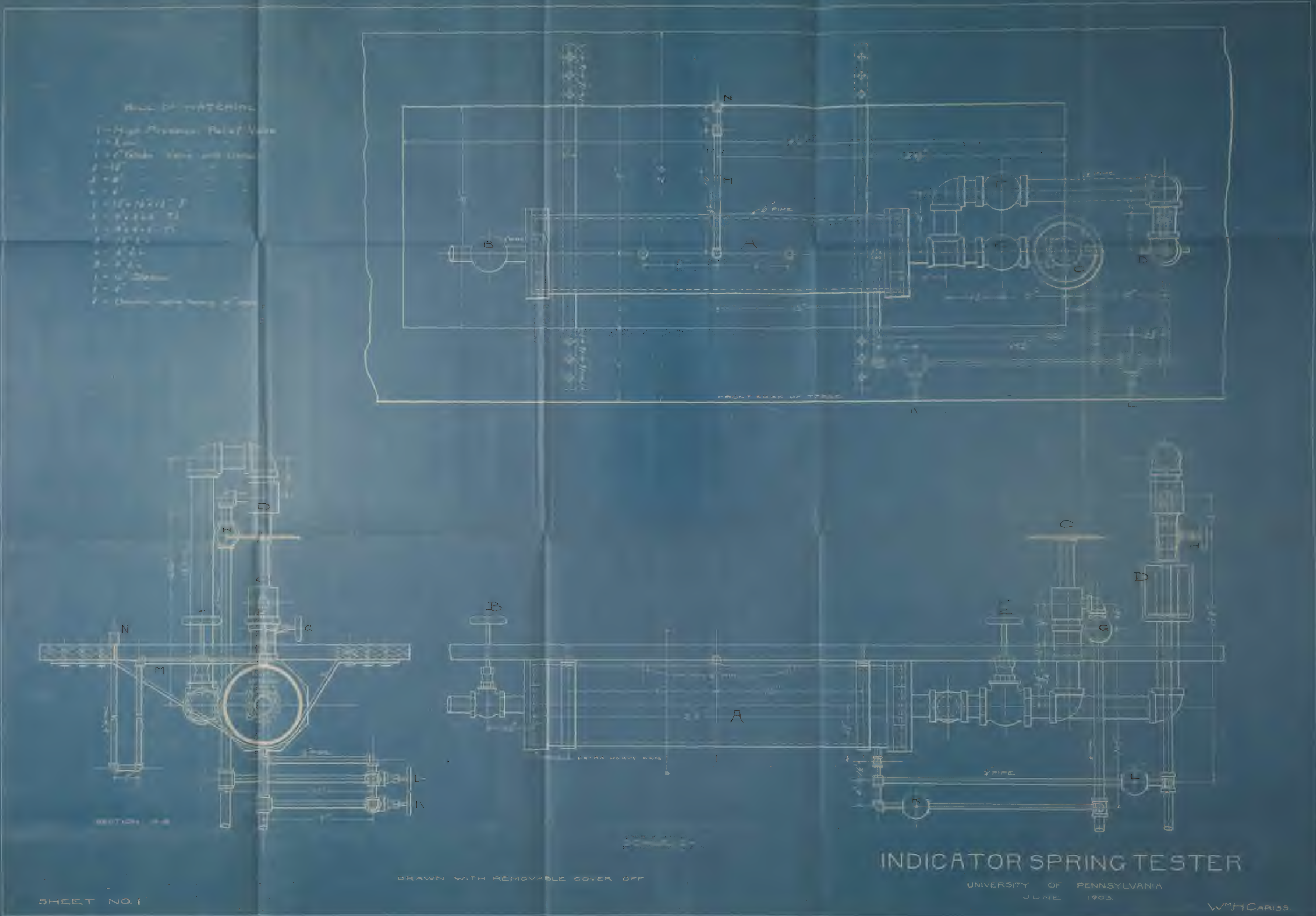
and draw the atmosphere line.
In taking the lines first press the pencil down, let it come up and draw the line. Then pull it up a little way, let it go down and draw the line. This is perhaps as good a method as we can use in an effort to eradicate the absolute or mechanical error which is always present and cannot be accurately allowed for.

To get the next line close B a trifle, take a weight off c and repeat as for the other pressure. It may be found that when the

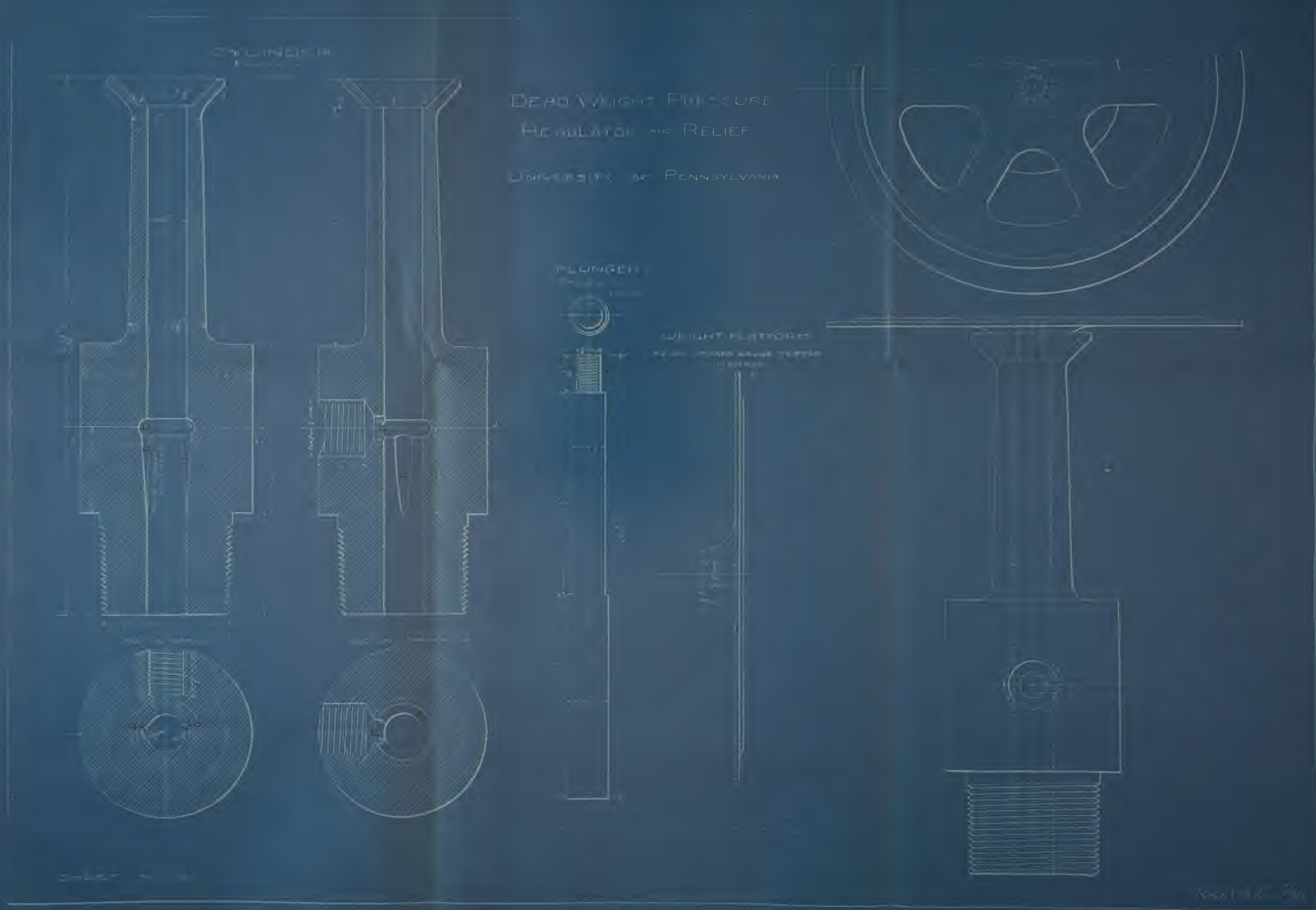
pressures get low better results can be obtained with the drip valve K slightly opened.

For pressures lower than the atmosphere. First open L, then F and H with no weights on D. Close L and open B very slowly and not necessarily all the way. H may now be be partly closed. Adjust B and H till the piston of D floats free and steady. Give the weights a rotatory motion and draw the lines as before described. A lower pressure may now be obtained by putting another weight on D. Adjust B and H as before. So on to the lowest attainable

pressure. When this is reached B will be very nearly completely closed and H will be open wide. It may be found advantageous at this point and near here to have valve L on the drip line to the condenser a little open.



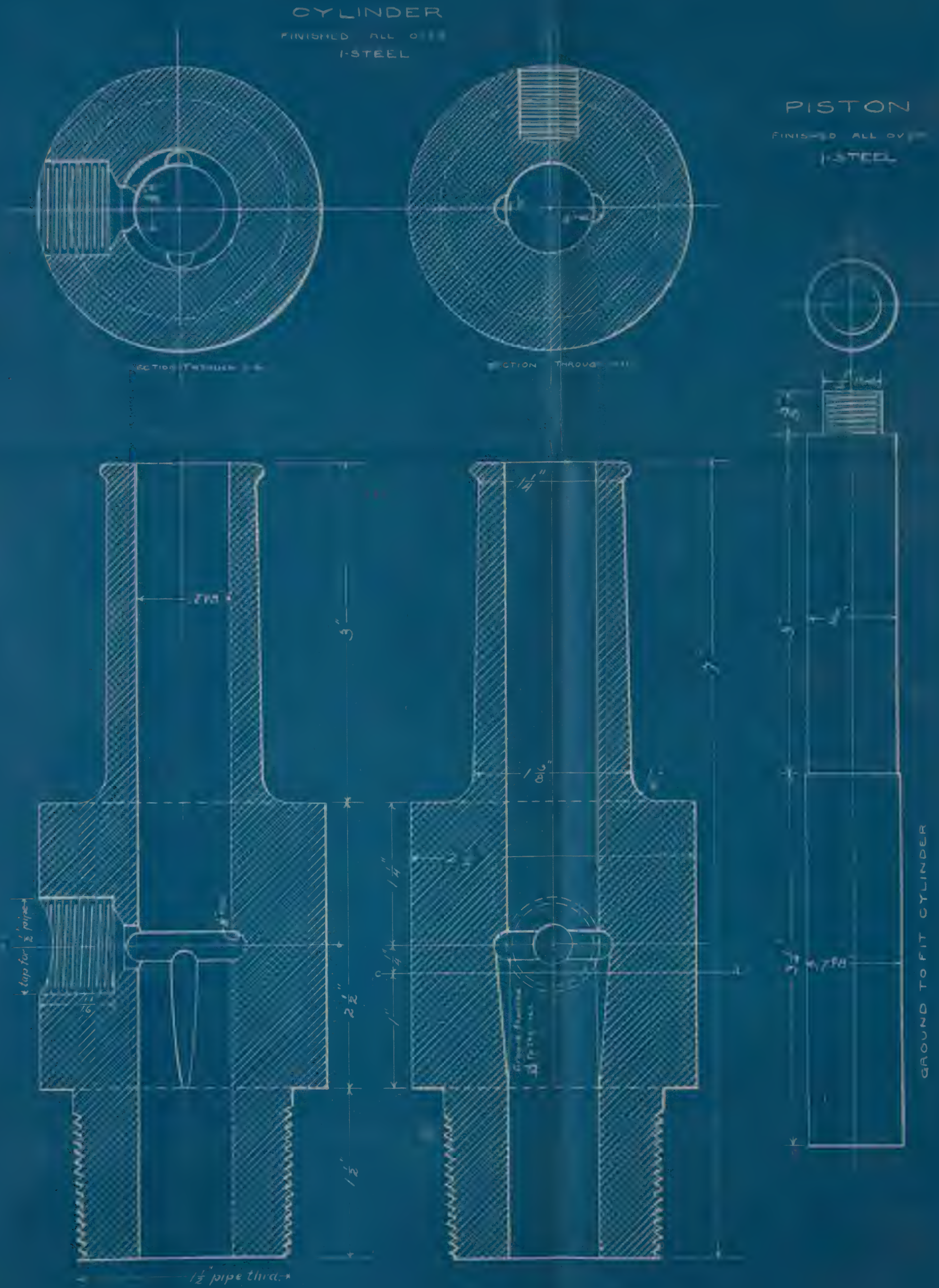
FRONT EDGE OF TABLE
SECTION A-B
DRAWN WITH REMOVABLE COVER OFF
INDICATOR SPRING TESTER
UNIVERSITY OF PENNSYLVANIA
JUNE 1903
Wm H Cariss
SHEET NO. 1



DEAD WEIGHT PRESSURE
REGULATOR AND RELIEF
UNIVERSITY OF PENNSYLVANIA
CYLINDER
PLUNGER
WEIGHT PLATFORM

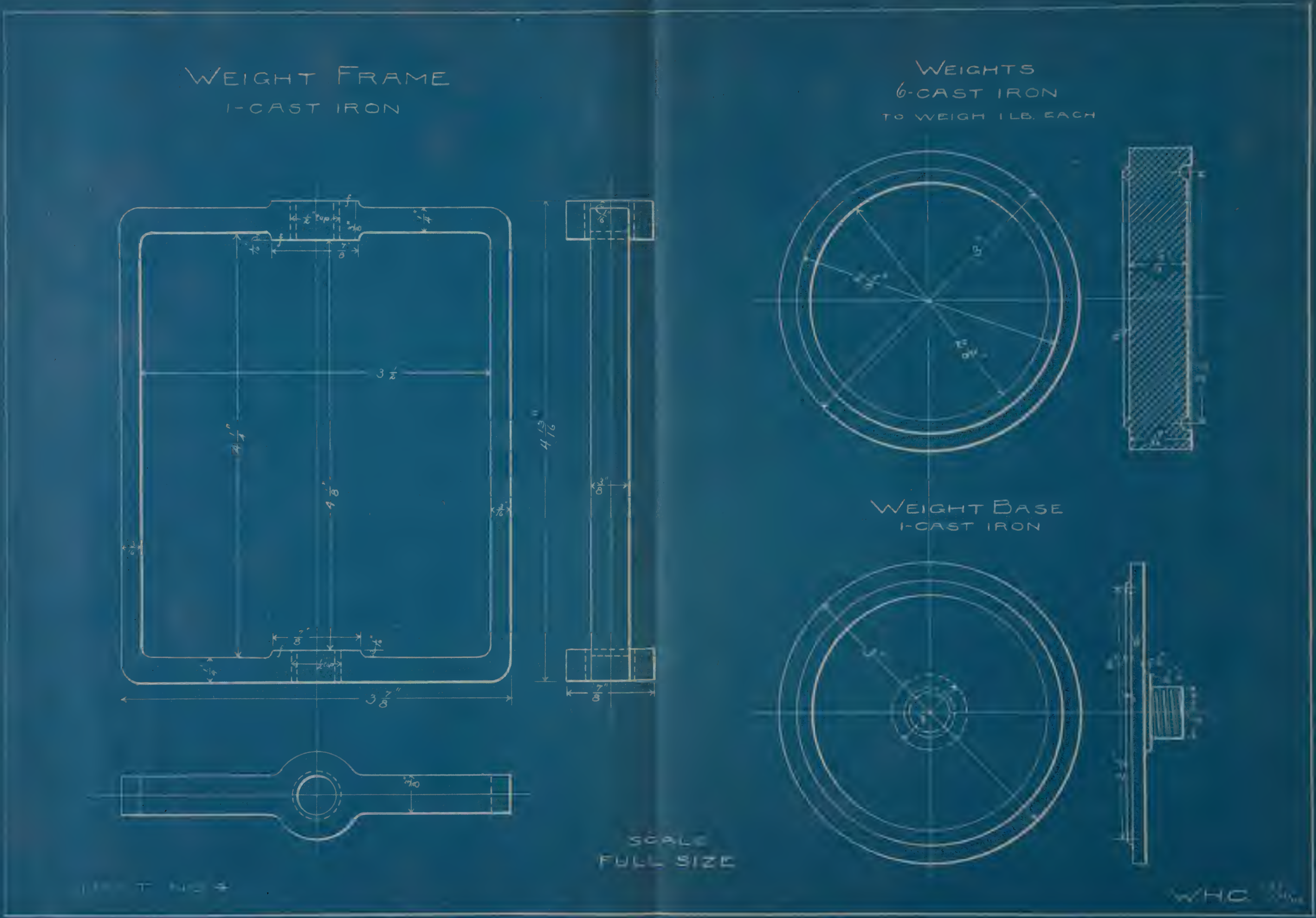
DEAD WEIGHT PRESSURE REGULATOR AND RELIEF

UNIVERSITY OF PENNSYLVANIA



SHEET NO. 3

W.H.C. 6/6/03.


WEIGHT FRAME
1-CAST IRON
$3\frac{1}{2}''$
$3\frac{7}{8}''$
$4\frac{13}{16}''$
$\frac{7}{8}''$
WEIGHTS
6-CAST IRON
TO WEIGH 1 LB. EACH
3"
WEIGHT BASE
1-CAST IRON
SCALE
FULL SIZE
W.H.C.